



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

IN REPLY REFER TO:

INSTRUMENTS OF SPACE

by

G. A. Vacca
Chief, Instrumentation and Data Processing
Electronics and Control Division
Office of Advanced Research and Technology

Presented to the Instrument Society of America
Boston, Massachusetts
November 2, 1964

Instruments and instrumentation are fundamental to the advancement of engineering, science and technology. Since NASA's prime mission--stemming from the National Aeronautics and Space Act of 1958--is the expansion of human knowledge, we must be very much concerned with instrumentation. You who are interested in instruments will particularly agree that instrumentation and metrology distinguish idle curiosity from scientific, businesslike, research. It is only when we can quantize and associate numbers with natural or man-made phenomena that we can understand and discuss such phenomena effectively.

The dictionaries have a variety of definitions for instruments and instrumentation, and I'm sure there are many different definitions to be found among the engineering societies and the scientific community. In the exploration of space, we could think of the entire assemblage of a launch facility, launch vehicle, satellite or spacecraft, the tracking and data reduction network and all the components and subsystems down to microminiature sensors and transducers as comprising an "instrument system." This might even include the operators and astronauts. Although this would be an extremely broad definition, nevertheless, one of the fundamental purposes of all these elements is to measure and acquire engineering, scientific and medical data--which, after all, is the purpose of most instruments.

Hard copy (HC) 2.19

Microfiche (MF) 50

I will try to describe very briefly some of the major NASA "Instrument Systems", within this broad definition, tell you about their basic objectives, and then discuss some of the devices and developments which would be more commonly defined as "instruments".

The projects I will describe are directed by NASA Headquarters, nine major Field Centers and the Jet Propulsion Laboratory. Of these nine Field Centers, the Electronics Research Center is our newest, and one which you undoubtedly have heard of and will hear more of in the future.

Frequently, people forget that the second letter in "NASA" stands for "Aeronautics", and that we are responsible for doing research in that field. To illustrate, Slide (1) shows a picture of the X-15 airplane and some of the work being done with this vehicle which is now called the "work horse"--at NASA's Flight Research Center at Edwards, California because it has flown so well so often. Problems in aerodynamics, structural heating, stability and control, and piloting are being investigated. Slide (2) shows an artist's concept of three configurations of hypersonic aircraft. Developments of this nature, along with related research, are done at several NASA Centers utilizing wind tunnel, environmental and other test facilities, such as those at Langley Research Center in Hampton, Virginia, Ames Research Center at Moffett Field, California and Lewis Research Center in Cleveland, Ohio.

Moving out into thinner air, the next Slide (3) shows the S-6 Atmospheric Structure Satellite. Some of the instruments used on that satellite, which is known as Explorer XVII, are shown. This satellite was launched in 1963 to obtain data on energetic particles and fields near the earth. The family of satellites, shown in the next Slide (4) are the Synchronous Communication Satellites. The objective of these satellites, of course, is for better global communications. They are positioned approximately 22,000 miles above the earth in a circular orbit in a fixed position relative to the earth. The next Slide (5) shows a Tiros satellite. Tiros is an acronym for Television, Infrared Observation Satellite. The objective of satellites of this type is to assist meteorologists by providing cloud photos and other weather information to enable better weather forecasting. On the next Slide (6) is shown an Orbiting Geophysical Observatory--or "OGO". This satellite is designed to obtain scientific data in atmospheric physics, earth-sun and interplanetary phenomena.

Now, to talk about one of the programs which has received considerable public attention recently, the Lunar Program; let's look at Slide (7) showing the moon and some of the many questions scientists and engineers have asked about it, such as: Where can men land? What is the surface like? What is the origin of the craters? What is its gravity field? What is its composition? To answer these, and other questions, there are several efforts planned; some of which are illustrated on the next Slide (8). Here are three types of satellites--the Ranger VII which provided those truly excellent photographs of the moon last July was one of this family.

Moving farther out into space, on the next Slide (9) is shown an Advanced Orbiting Solar Observatory. This system is intended to obtain scientific information about the sun. Then, going still farther into space, on the next Slide (10) is shown an Interplanetary Monitoring Platform, affectionately called "IMP"--whose objective is to obtain data on interplanetary radiation, magnetic fields and other phenomena.

So far, you have seen illustrations of unmanned satellite projects. The next Slide (11) gives an indication of the magnitude of the very large "Instruments" required for manned exploration of space. Here are the Saturn family of launch vehicles, the largest of which, Saturn V, taller than the Statue of Liberty, is the one planned for the Apollo program to land a man on the surface of the moon.



Saturn An interesting ~~statistic~~ ^{fact} and a compliment to the instrument industry is that there ~~are~~ ^{used} approximately 1200 types of measurement involved in ~~a recent~~ ^{the} flight and approximately 1184 were completely successful. This is a remarkable achievement of Instrumentation performance.

Now, to turn to the instruments as they are more commonly defined in the space program--the next Slide (12) shows the fiber optic (stage separation) application as used in the SA-6. This next Slide (13) shows a possible future application of fiber optics--to permit on board observation of flame characteristics. There are other applications, of course.

In the next Slide (14) are shown various types of Ablation Sensors developed to detect heat shield and spacecraft heating and burnoff. The scheme on the left is a light pipe which transmits light to a photo detector--several of these would be placed at various depths. The simpler scheme, in the center, uses two wires which are shorted by ablation and can thus be made to produce a signal to be read out. The arrangement on the right is applicable to both charring and non-charring conditions and uses a tube and spring wire which, when deformed by heating, closes a switch and completes a circuit.

To illustrate one of the instruments used to obtain data on the earth's atmosphere, next is shown in Slide (15) a device developed at Langley Research Center to measure air density by means of backscatter of gamma rays. The object here is to get data in the undisturbed atmosphere, outside the boundary layer and turbulence surrounding the rocket. This method has been used successfully to altitudes of approximately 144,000 ft. and is being refined and extended to higher altitudes.

To obtain data on micrometeoroids, the transducer shown on the next Slide (16) was developed at Ames Research Center. This is a micro-balance using cantilever beams with piezo-electric sensors attached. This was found to be so sensitive that it has been adapted to measure heart beats of the embryo in bird's eggs as shown in the next Slide (17). The medical people are very much interested in this device in connection with research on the effects of drugs.

Previously I mentioned that NASA is responsible for research in Aeronautics. One of the difficulties in hypersonic tunnels and shock tubes, where very small models must be used, is the measurement of pressure, temperature and other parameters on the models. The next Slide (18) shows at the top a diagram of the arrangement of one of our hypersonic tunnels which uses a "pop gun" to launch the model. The speed here is of the order of Mach 10.0 and the time involved is very short as you can see on the bottom scale. In order to obtain base pressure measurements, a miniature telemetry system with a pressure transducer was developed by Ames Research Center. This curve at the bottom shows data obtained. Another miniature device developed at Ames for measuring low pressure is shown in the next Slide (19). This is a vibrating diaphragm, pressure transducer less than an inch long.

I mentioned earlier the conversion of a meteoroid transducer to measure bird heart beats--we are very much interested in the heart beats and other physiological functions of humans, particularly, the functioning of astronauts. They are very busy people and do not like to be encumbered with wires and other restricting attachments while performing their work. In order to allow as much freedom of movement as possible and still obtain medical data, the miniature telemetry unit shown on the next Slide (20), has been developed. This is about the size of a penny, yet it includes amplifier, oscillator and battery. This is not the smallest size in which this can be made, and it is applicable for electrocardiogram, electroencephalogram and electromyogram use. The medical profession is interested in these devices also to obtain continuous data on a patient without restricting his movements.

Another device for monitoring human performance, is the ear oximeter shown in the next Slide (21). This device contains a light source and photo detector. The variation in blood flow produces a variation in the light-absorbed and thus modulates the detector. It's a small and easily attached device but does not have an integral telemetry system (as yet).

Let us turn now to our needs and requirements. In the next Slide (22), you see an artist's view of three astronauts riding in an Apollo spacecraft and an observer on the ground attempting to monitor a few of their body parameters. One of the needs indicated here is for an integrated method which will be valid, yet quick and easy to interpret and give indications of over-all system status. For example, indication of the

total cardiovascular and nervous system behavior so as to show alertness and reaction rates; and a method of ~~extrapolating~~ extrapolating these to indicate the performance capability remaining--in other words, "How far can one still go?" This is a large order and would require close cooperation between the medical profession and instrument developers. There would be many ~~obvious~~ advantages in addition to the uses in space operations.

Some of our general instrumentation needs and requirements are outlined in the next Slide (23):

1. Range of measurement needs extension two ways-- to higher values, to lower values; and we need techniques to measure new parameters.
2. We need more accurate measurement ability, particularly at the extreme ends of present scales.
3. We need combinations of measurements to reduce the number of measurements, and we must eliminate synergistic effects so that we can more easily measure a given parameter without having to compensate for others.
4. We need better standards and calibration methods.
5. Absolute methods of calibration are particularly needed.

Some of the various kinds of instrumentation which might be required for a manned orbiting space station are listed on the next Slide (24). Of the items listed, some of the more critical ones needing development, not necessarily for space stations, but for a variety of space ~~requirements~~, are:

Vacuum Instruments for 10^{-10} to 10^{-16} torr

High Temperature Instruments ^{beyond} ~~to~~ $3,000^{\circ}\text{C}$

Low Temperature Instruments to 4°K and below

Advanced UV Instruments and Particle Instruments

X-15 RESEARCH AIRPLANE

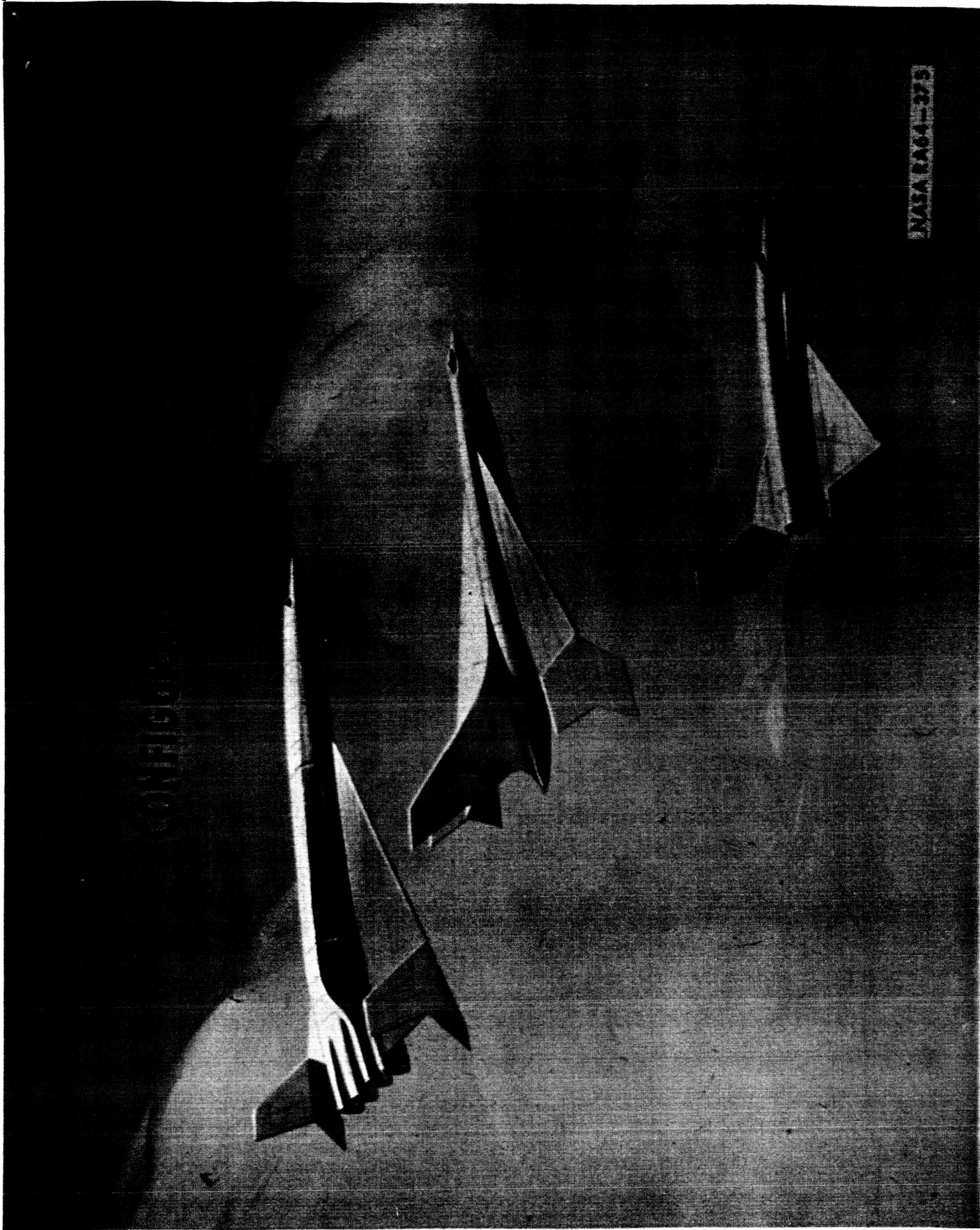
AERODYNAMIC AND
STRUCTURAL HEATING

HYPERSONIC STABILITY
AND CONTROL

CONTROL AT EXTREME
ALTITUDE

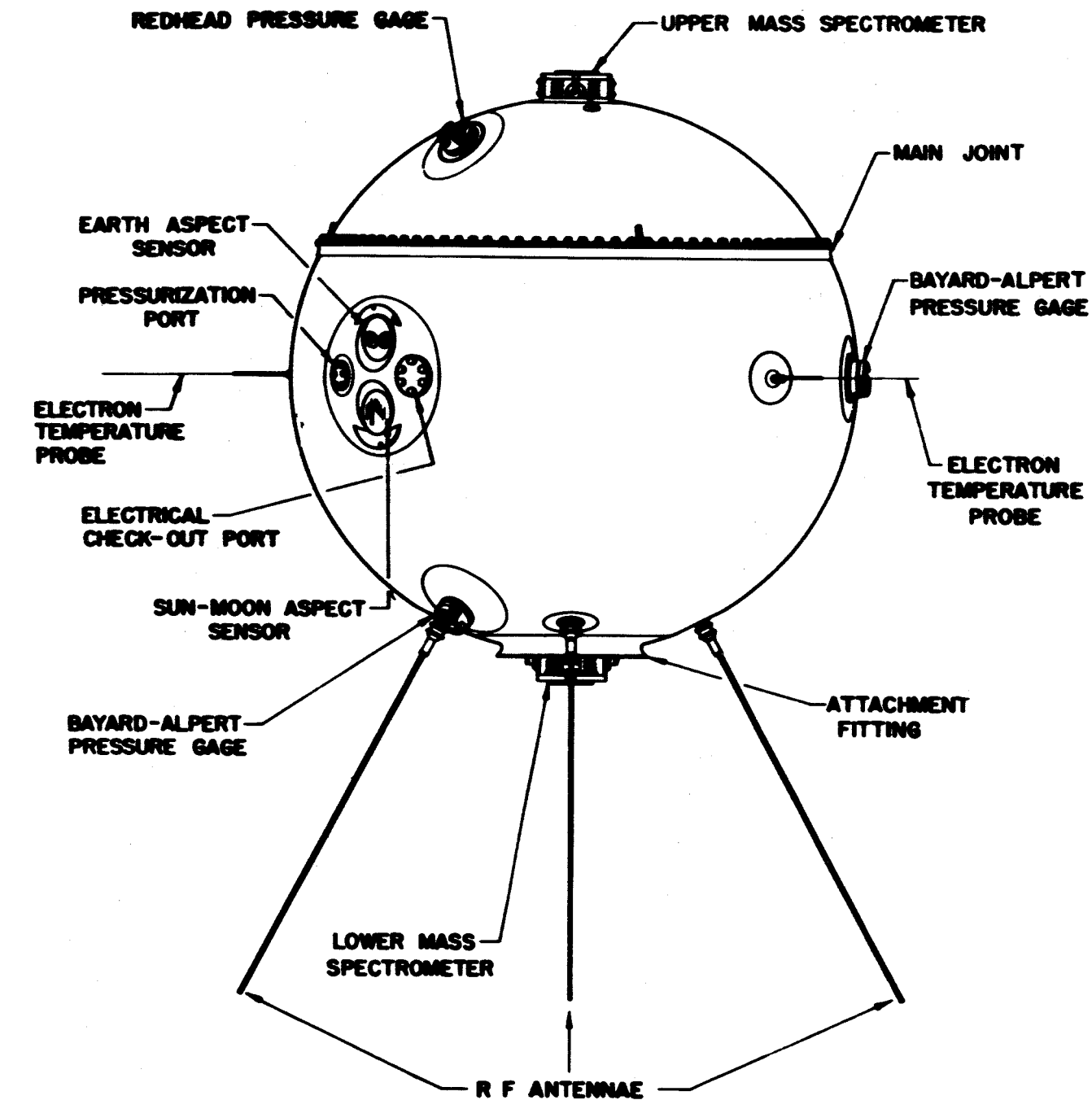
PROGNOSTIC PROBLEMS





NAV 6364-373

S-6 ATMOSPHERIC STRUCTURE SATELLITE



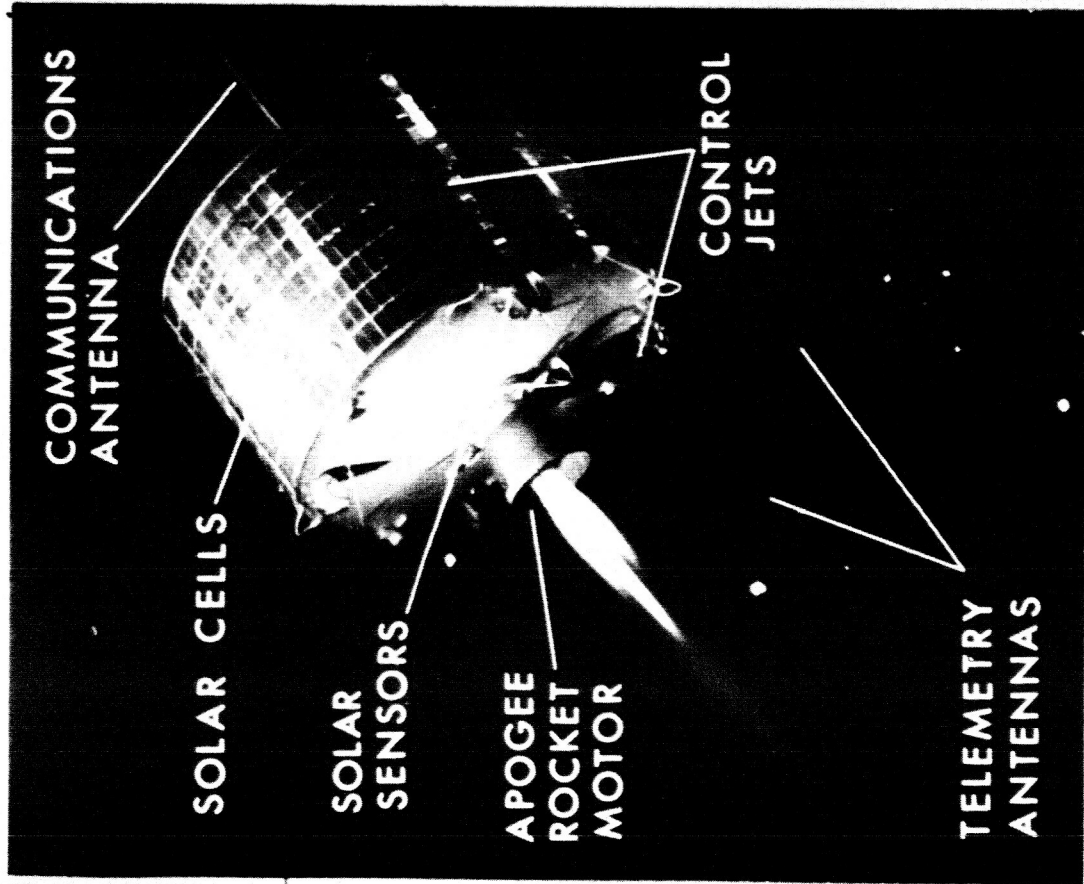
0 3 6 9 12
SCALE: INCHES

1-1-0

SLIDE (3)

SYNCOM SPACECRAFT

ACTIVE SYNCHRONOUS COMMUNICATION SATELLITE



LAUNCH WEIGHT 146 LBS.

CONTROL SYSTEMS GAS JETS

PROPELLANT SOLID

STABILIZATION SPIN

STATUS

SYNCOM I LAUNCHED FEB. 14, 1963
ACHIEVED NEAR SYNCHRONOUS
ORBIT

SYNCOM II LAUNCHED JULY 26, 1963
ON STATION AUG. 16, 1963 AT 55° W
COMMUNICATIONS "ON" TIME
OVER 2000 HOURS.

SYNCOM III LAUNCH 1964 INTO
SYNCHRONOUS EQUATORIAL ORBIT
OVER THE PACIFIC OCEAN.

NASA ST64-227

REV JAN 1964

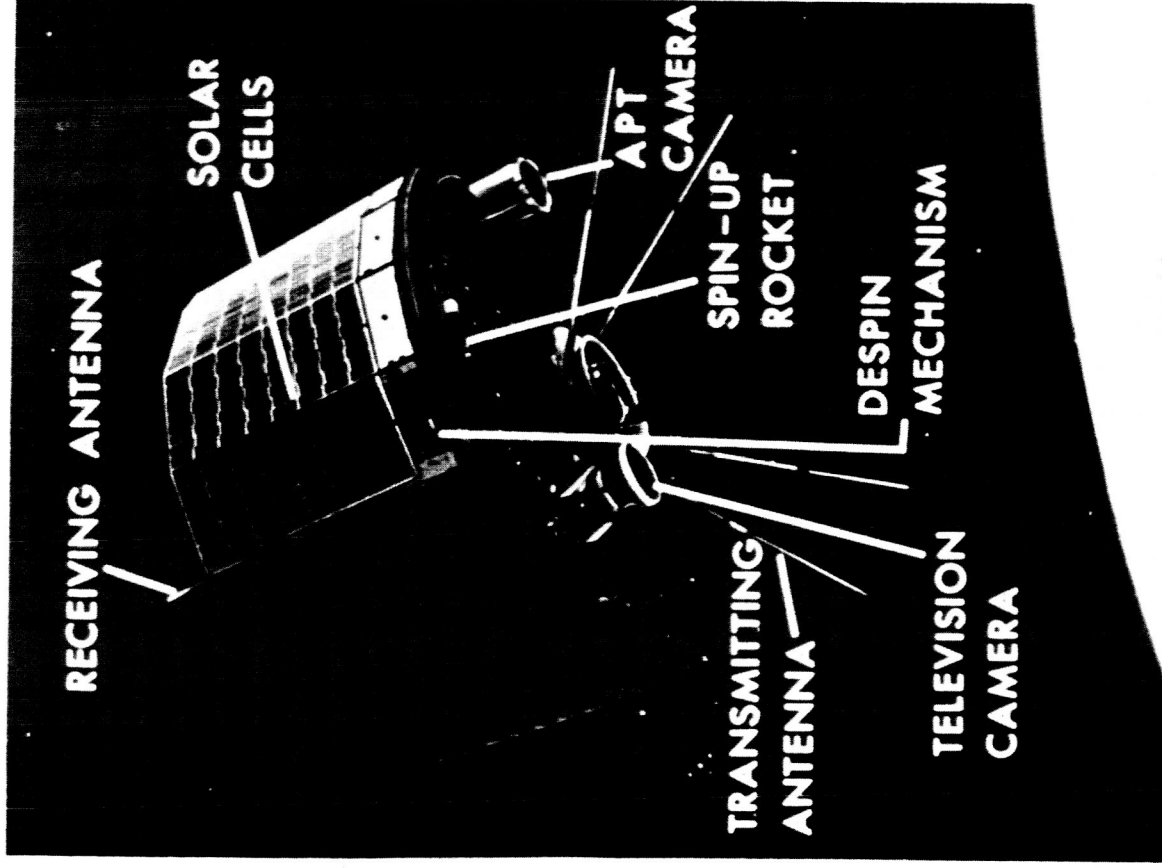
SLIDE (4)

TIROS VIII

GROSS WEIGHT	265 LBS.
INSTRUMENT WEIGHT	51 LBS.
SENSORS	1 TV CAMERA 1 AUTOMATIC PICTURE TRANSMISSION SYSTEM
POWER	20 WATTS
STABILIZATION	SPIN
DESIGN LIFE	4 MONTHS
LAUNCH VEHICLE	DELTA
ORBIT	APOGEE 470 MI. PERIGEE 440 MI. INCLINATION 58.5°
STATUS	TIROS VIII LAUNCHED 21 DEC ,1963

NASA SF64 270
REV JAN 1964

SLIDE (5)



ORBITING OBJECT

SOLAR
PANEL

GAS STORAGE

ATTITUDE CONTROL
UNIT

ANTENNA

HORIZON
SCANNERS

DATA
SYSTEMS

PLAN

NON-REENTRANT
POLAR ORBIT
NEAR CIRCULAR
POLAR ORBIT

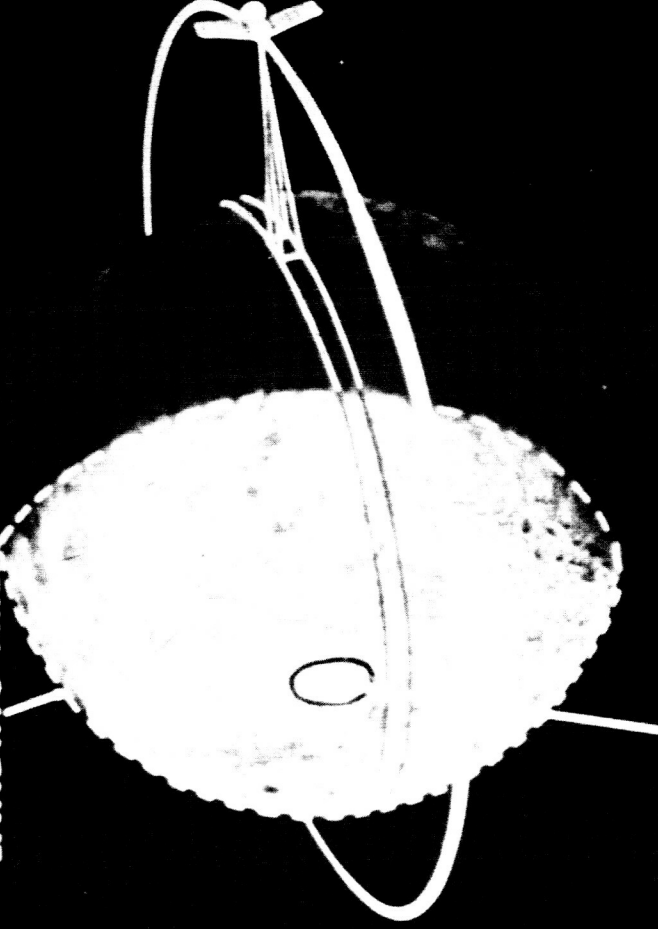
FIRST FLIGHT-1964

NASA 5064-190
REV 9-64

LUNAR EXPLORATION

SURVEYOR

LANDING AREA



RANGER

IMPACT AREA

- WHERE CAN MEN LAND?
- ARE THERE LARGE FLAT AREAS?
- IS IT COVERED WITH DEEP DUST?
- IS IT RADIOACTIVE?
- WHAT IS THE ORIGIN OF CRATERS?
- WAS IT FORMED LIKE THE EARTH?
- WHAT IS ITS TEMPERATURE?
- ARE THERE BOULDERS OR CRACKS?
- WHAT IS ITS GRAVITY FIELD?

UNMANNED LUNAR SPACECRAFT

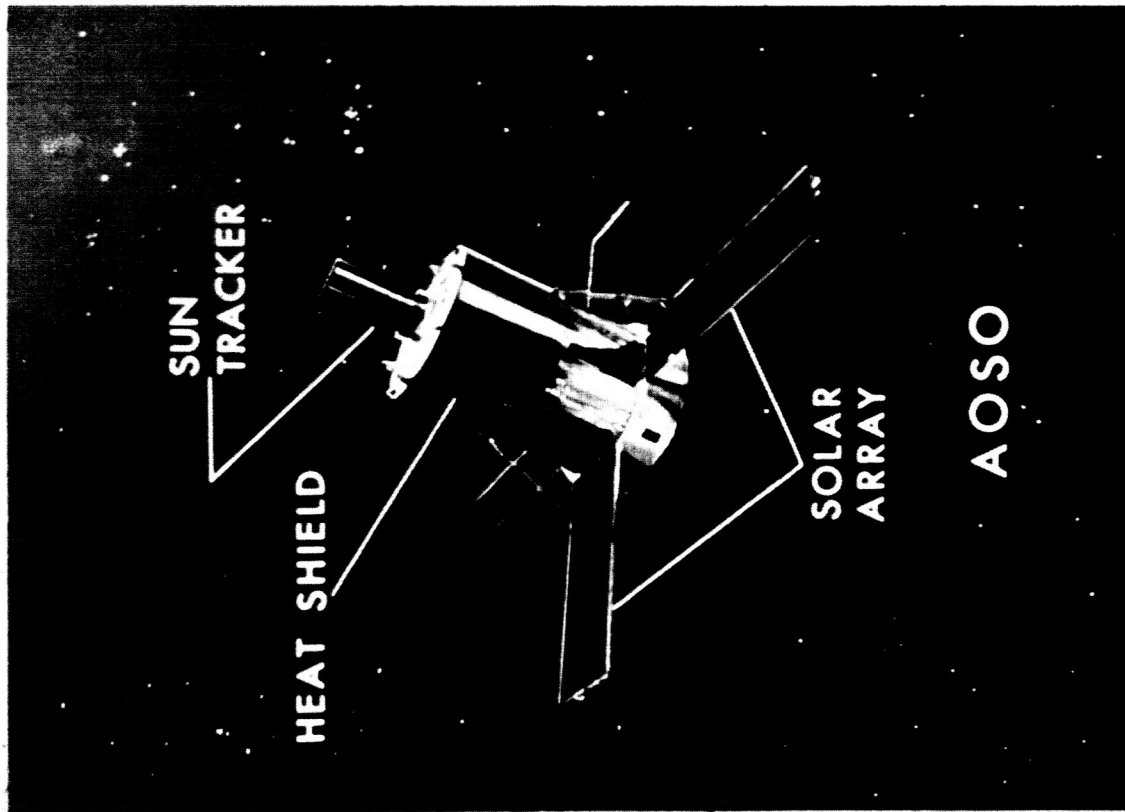
SURVEYOR
(ORBITER)

RANGER

SURVEYOR
(LANDER)



ADVANCED ORBITING SOLAR OBSERVATORY



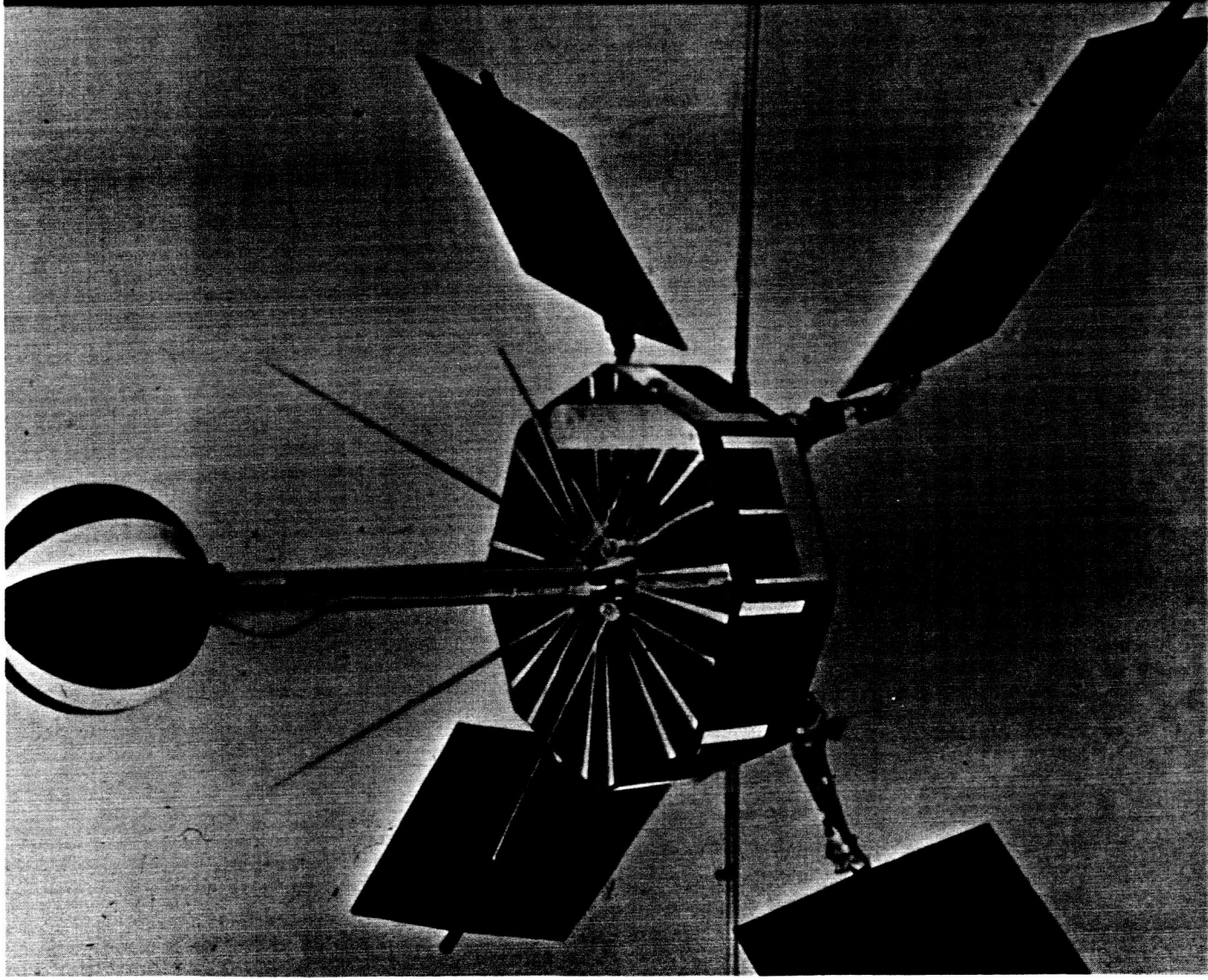
GROSS WEIGHT	900 LBS.
INSTRUMENT WEIGHT	250 LBS.
INVESTIGATIONS	4 TO 6 POINTED
POWER	400 WATTS
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	ONE YEAR
LAUNCH VEHICLE	AGENA
ORBIT	CIRCULAR 345 MI.
PLAN	FIRST FLIGHT SOLAR MAXIMUM

NASA SG64 194
REV JAN 1964

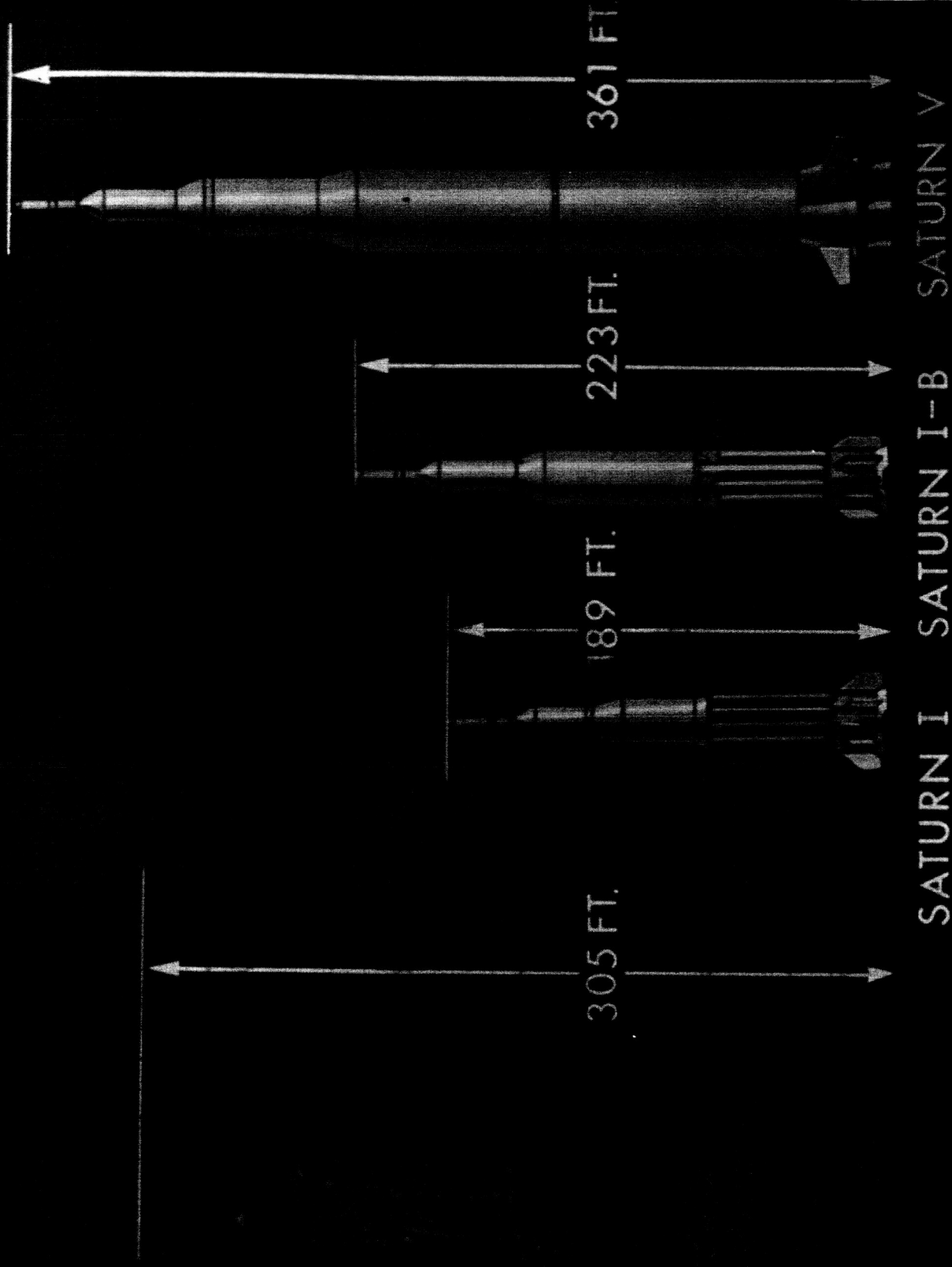
INTERPLANETARY MONITORING PLATFORM

NASA SG63-1988a

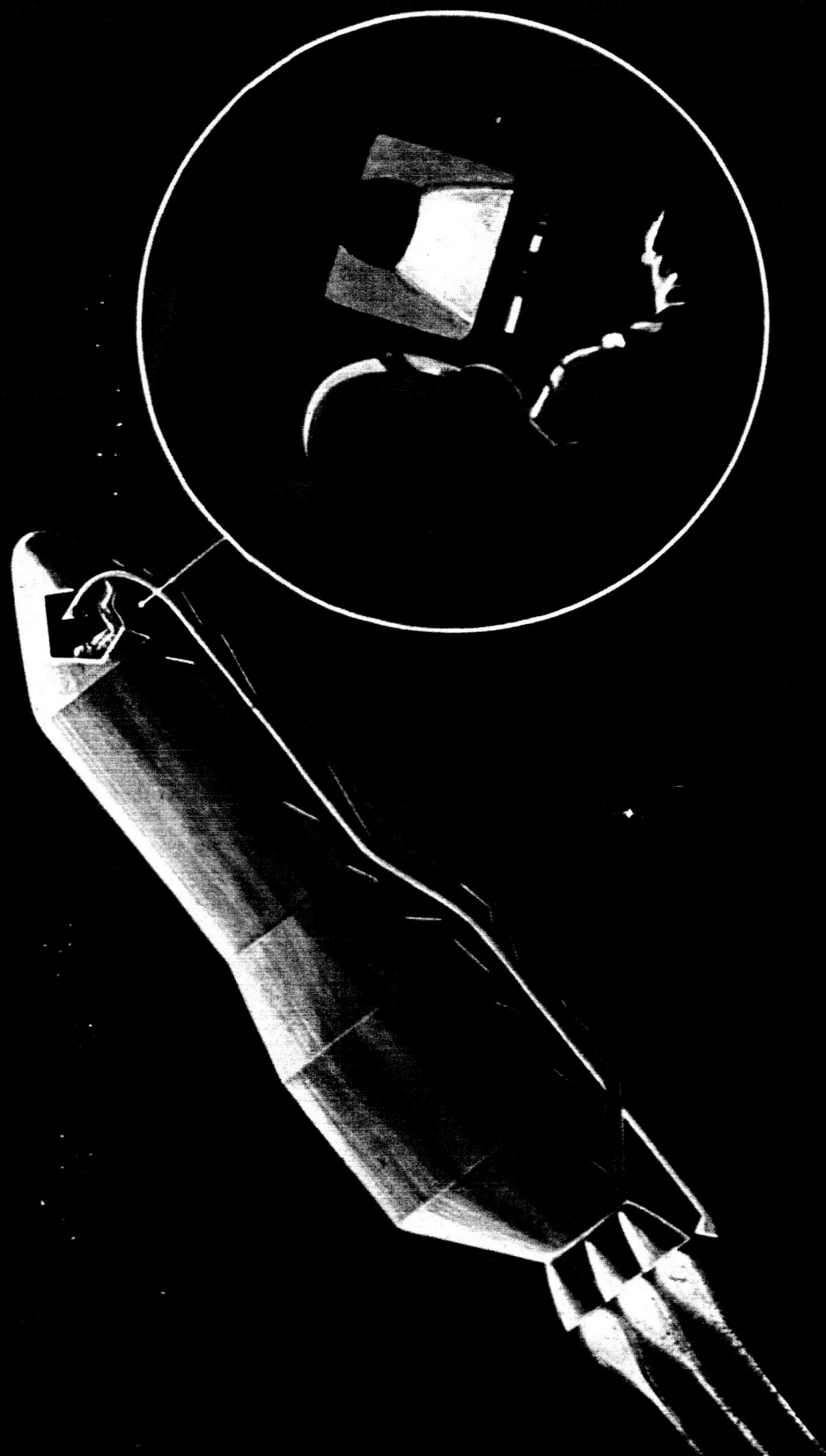
SLIDE (10)



LARGE LAUNCH VEHICLES



FIBER OPTICS (FUTURE USE)



NASA R63-989

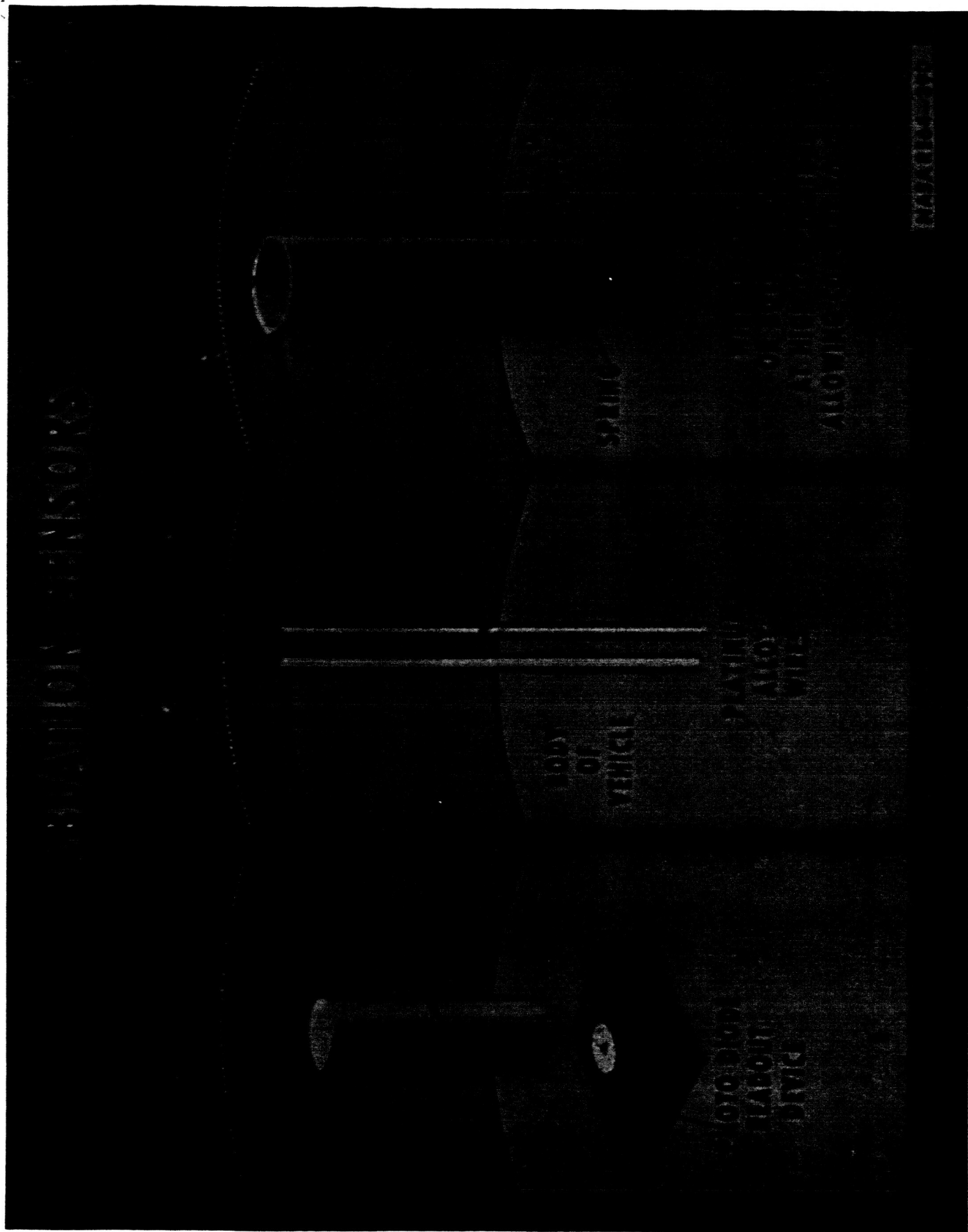
SLIDE (13)

FIBER OPTICS

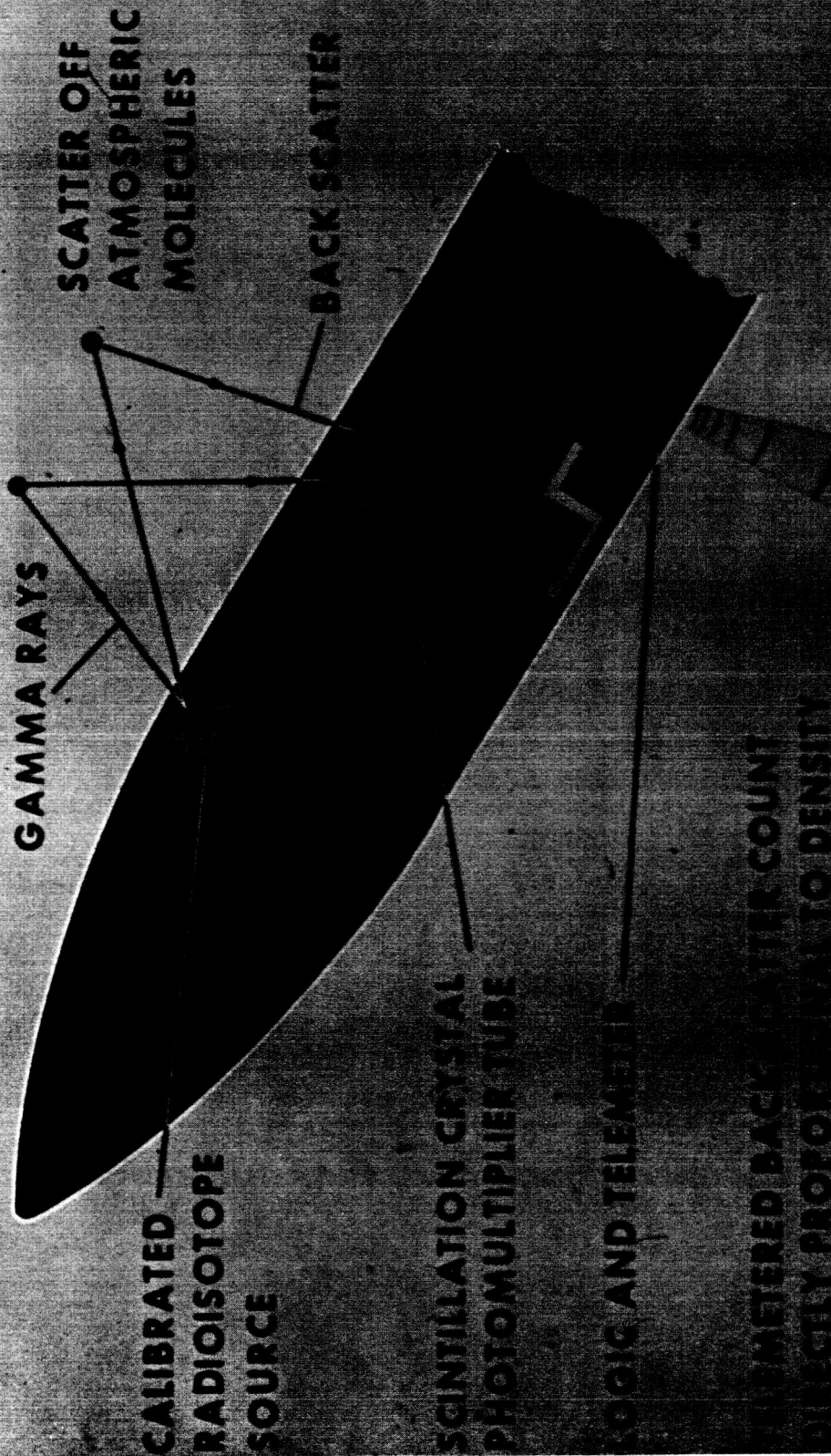
(PRESENT USE)

LENS

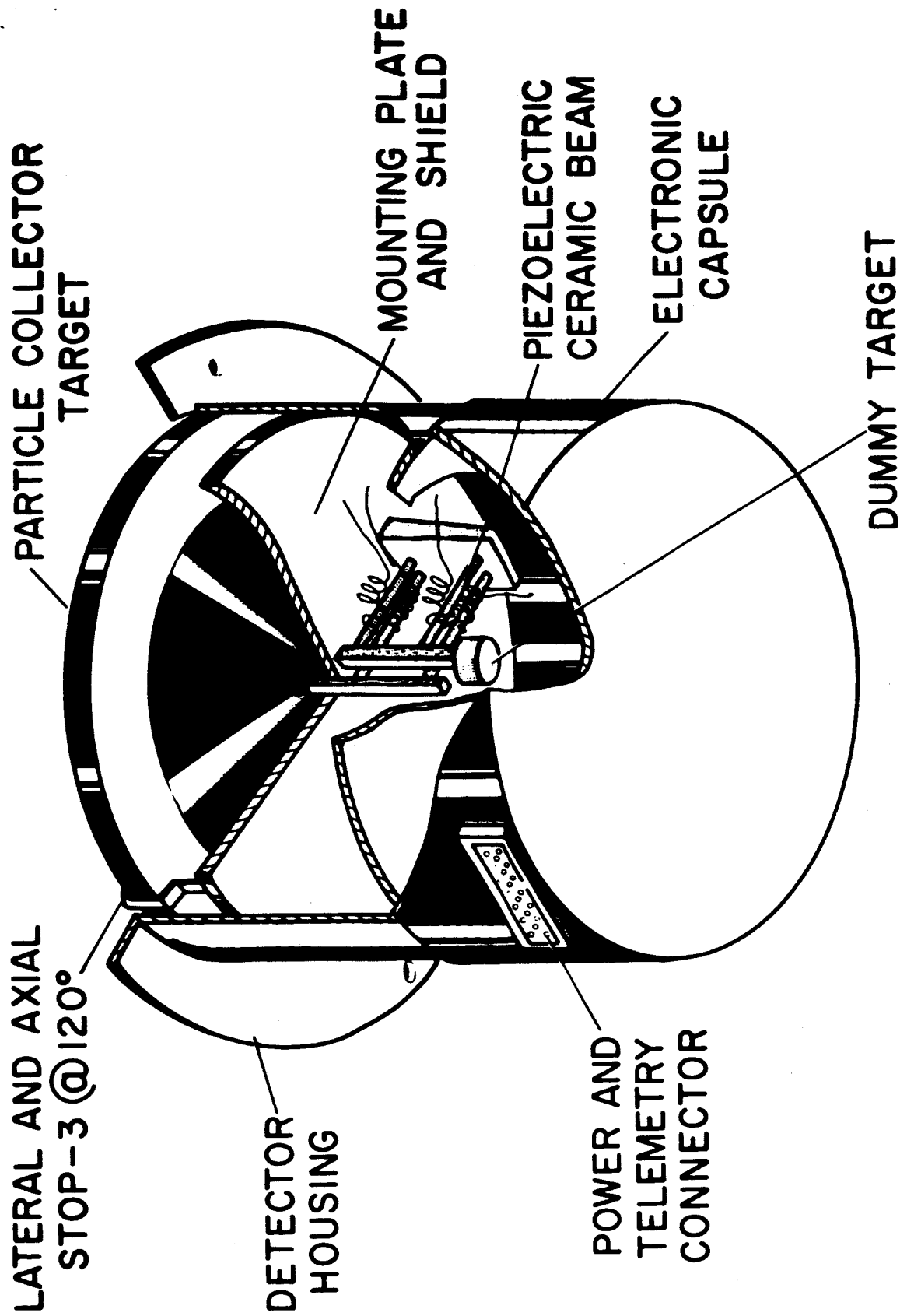
RECOVERABLE
CAMERA
PACKAGES



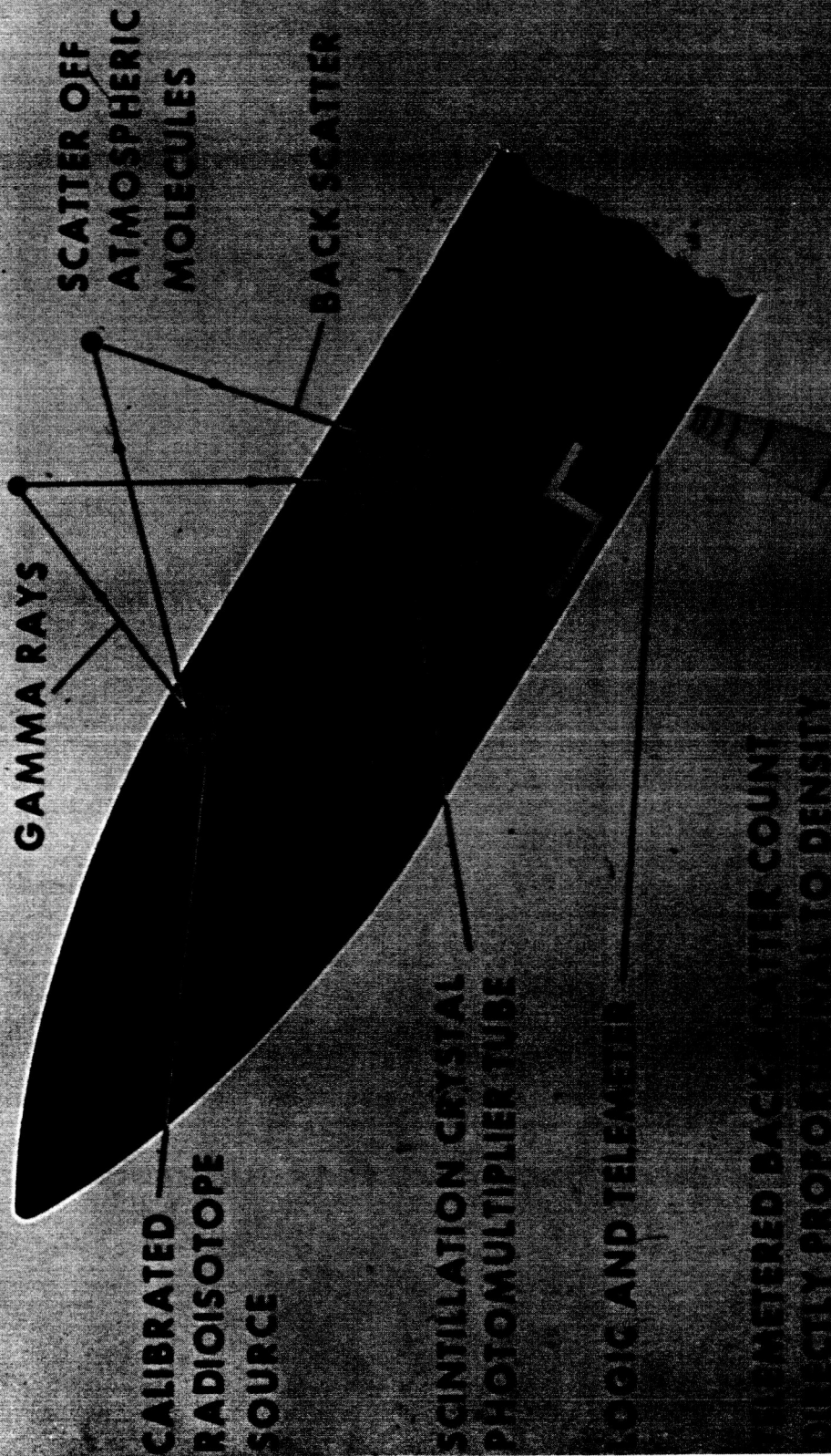
AIR DENSITY INSTRUMENTATION



NASA R63-111

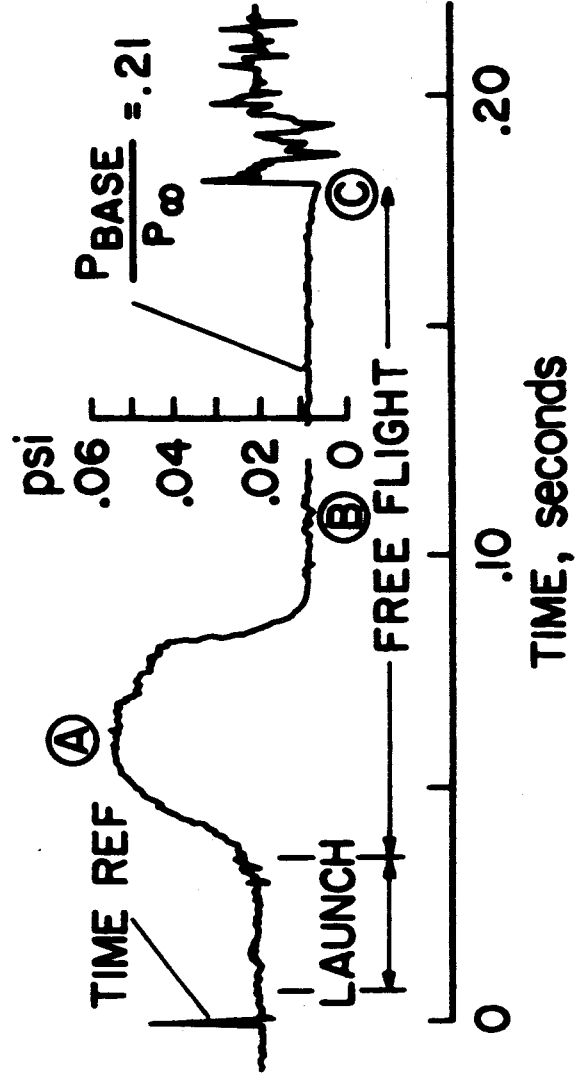
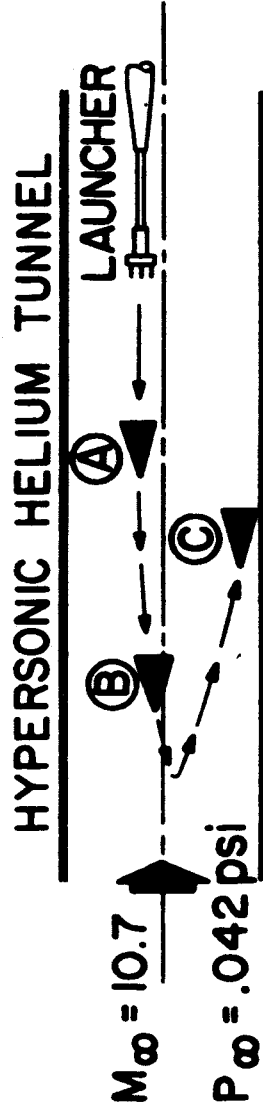


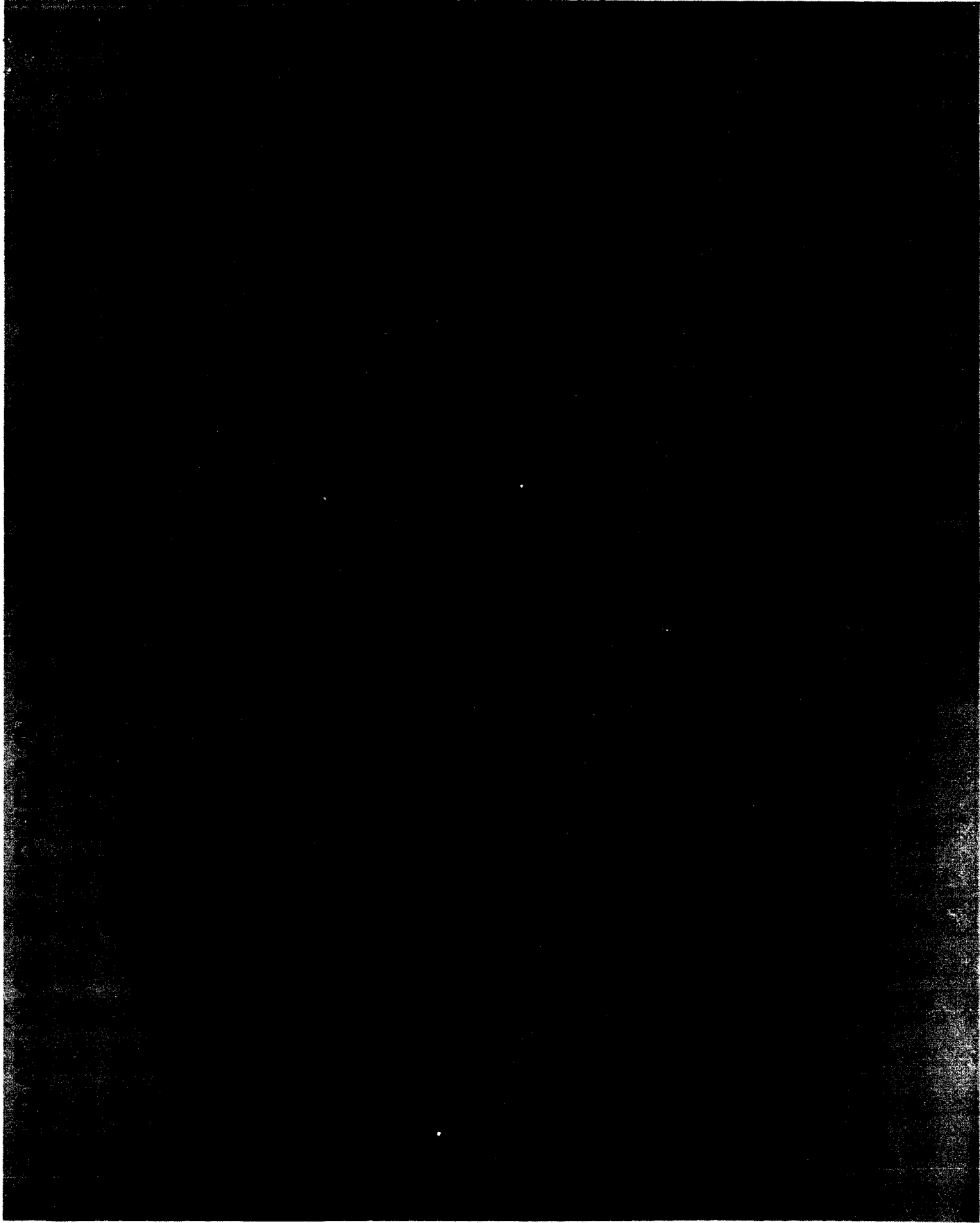
AIR DENSITY INSTRUMENTATION



NASA R63-111

BASE-PRESSURE MEASUREMENT BY PRESSURE TELEMETER FROM A CONE IN FREE FLIGHT



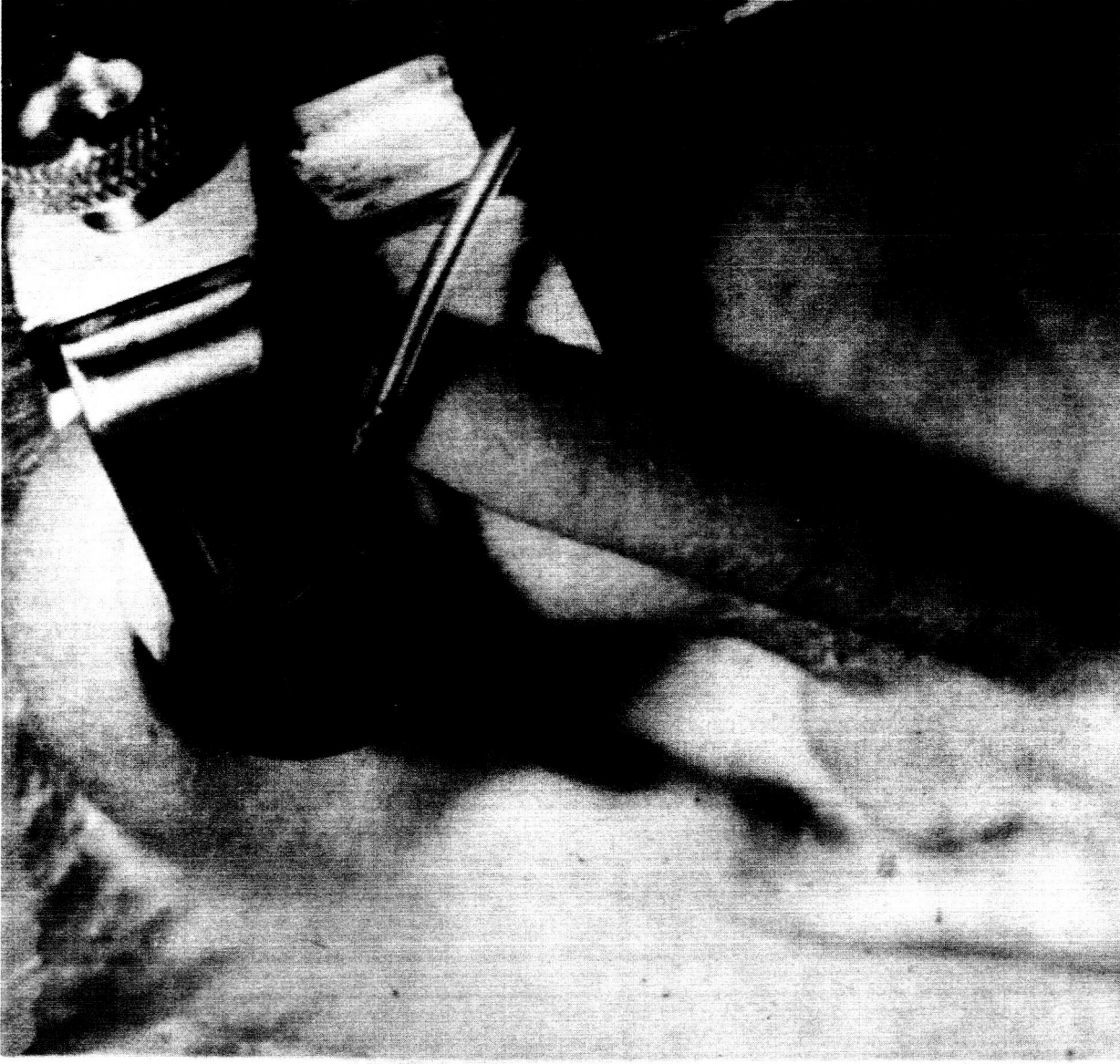


SLIDE (19)

IMPLANTABLE BIOMEDICAL TEMPERATURE
TELEMETRY UNIT



**EAR OXIMETER - BLOOD
PRESURE MONITOR**

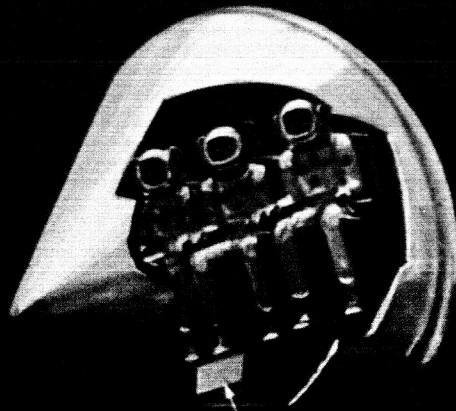


BIOMEDICAL SENSORS

MICROMINIATURE SENSORS

- HEART
- RESPIRATION RATE
- BLOOD PRESSURE
- TEMPERATURE

RELAY



INSTRUMENTATION GENERAL NEEDS

RANGE OF MEASUREMENT

DYNAMIC RESPONSE (REVEAL INTER-ACTING PHENOMENA)

RELIABILITY

LIFE

SIZE, WEIGHT, POWER

MATERIALS (e.g., REFRACTORIES)

CALIBRATION

STANDARDS

SYNERGISTIC EFFECTS

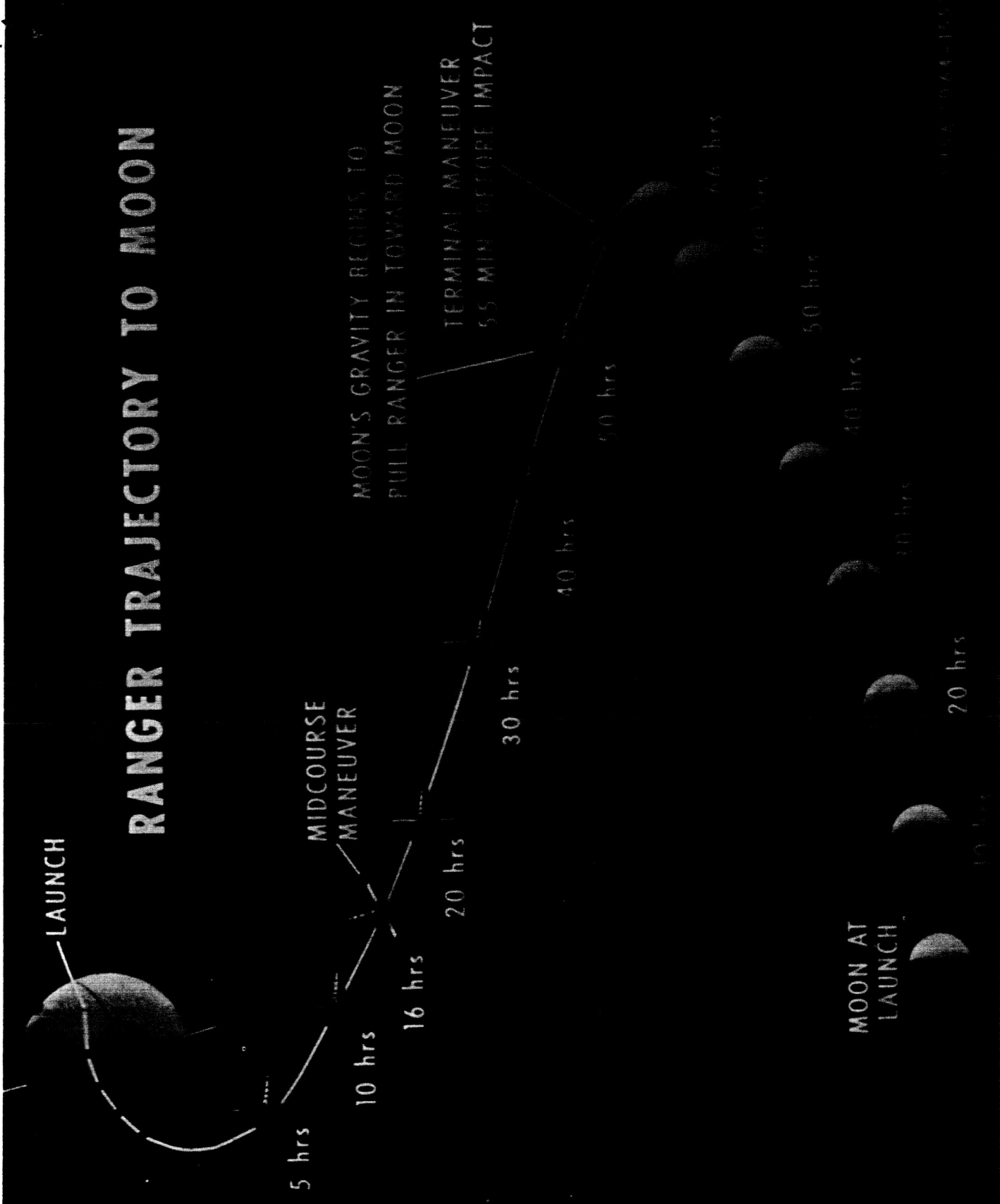
ZERO-G OR LOW-G ENVIRONMENT

DIRECT DIGITAL MEASUREMENT

TYPICAL INSTRUMENTATION FOR SPACE STATIONS

Spacecraft Integrity	Biomedical Surveillance	Scientific Observation	Calibration and Standards
Vacuum Gages	Electrocardiograph	Magnetometers -(Interplanetary Magnetic Fields)	Vacuum Calibration System
Leak Detectors	Respiration Rate and Volume Measurements	Telescopes (Stars, Nebulae)	Voltage Standards
Meteoroid Detectors	Metabolic and Circulatory Measurements	UV Spectrometers (Sun)	Mass Measurement under zero-g
Mass Flow Meters	Gas Chromatograph for Organic Trace Components	IR Spectrometers (Earth) (5-50 microns)	Accelerometer Calibration
Cryogenic Pressure Gages	Life Support System Control	Radio-Astronomic Measurements	Black Body Reference Source
Cryogenic Temperature Gages	IR Detector for Carbon Dioxide	Charged Particles and Plasma Analyzers	Time Standard
Accelerometers ($10^{-7}g$)	Oxygen Partial Pressure Gauges	Diurnal Thermal Gradient Measurement	Frequency Standard
Mass Spectrometers	Water Reclamation Control Devices	Planetary Radiation Measurement	Light Flux Standard
Gas Chromatograph		Cosmic Ray Detectors	Standard Radiation Source
TV Surveillance		X-Ray Measurements	Pulse Signal Standards

RANGER TRAJECTORY TO MOON



WAC-064-135

RANGER BLOCK III

[BASED ON RANGER VII DATA]

GROSS WEIGHT	807 LBS.
INSTRUMENT WEIGHT	382 LBS.
INVESTIGATIONS	6 TV CAMERAS
POWER FROM SOLAR PANELS	180 WATTS
POWER REQUIRED	117 WATTS
STABILIZATION	3 AXIS ATTITUDE CONTROL (COLD GAS)
DESIGN LIFE	69 HR. TRANSIT
LAUNCH VEHICLE	ATLAS D/AGENA B
TRAJECTORY	LUNAR IMPACT
PLAN	TWO FLIGHTS IN 1ST QUARTER 1965

NASA 5164-199
REV 9-4-64

